October 23, 2001

RHIC E-Cool Note on

Electron Gun Cooling

Cooling the electron gun is rather demanding. At 15 MV/m on the cathode, the total expected heat load on the gun is about 654 kW with a heat flux of 390 W/cm^2 at the hottest spot. This is a preliminary estimate based on a 2½-cell design. Calculations performed by Dong Wang for 1.8782 MV/m yielded a total power of 10.2522 kW, which when scaled up to 15 MV/m results in a total power of 654 kW.

Using high quality copper, the highest attainable water-cooling rate (without undergoing a phase change) is about 250 W/cm^2. Exceeding this rate can be achieved by making the surface area, across which heat is transferred to the water, larger than the surface area on which heat is deposited. Increasing the surface area that is in contact with the water is relatively easy. Grooves, saw teeth, etc., cut into the cooling channels will increase that surface area. However, ensuring adequate water flow in each and every channel is non-trivial. Any stagnation in water flow (or even an eddy) in any groove or channel can have disastrous consequences.

In our case, large water flow is needed to remove more than ½ MW of total heat load in addition to achieving a cooling capability that exceeds 390 W/cm^2 (it was decided to aim for 500 W/cm^2). Thus the crux-of-the-matter is to maximize both total water flow and the surface area in the cooling channels, while ensuring adequate flow through each and every channel. Northrop Grumman has the capability (which is highly proprietary) to design (codes to calculate water flow) and to fabricate the cooling system. A good scenario would be for BNL and AES to design and fabricate parts of the RF cavity to which Northrop Grumman would add a cooling system.

Some additional comments:

Similar cooling systems have achieved 2 kW/cm^2, and in extreme cases as high as 5 kW/cm^2 were accomplished with nucleated boiling (not recommended for us).

Recently, there was a report that thermoelectric devices (a.k.a. Peltier coolers) have achieved cooling of 700 W/cm^2, which is two orders of magnitude higher than the state-of-the-art. **Incorrect!** Study showed (in a laboratory device) enhancement by a factor of 2.4, and there was a claim of a potential to eventually pump a heat flux of up to 700 W/cm^2 (please see Nature 413, 597-602 [2001]).